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ABSORPTION OF THERMAL NEUTRONS IN INDIUM[1]

BY H. FEENY[2]

Abstract

Absorption of thermal neutrons by indium leads to the formation of three radioactive periods, whose half-lives are 13 sec., 54 min., and 48 days. The relative contributions of these periods to the total capture cross-section of indium for thermal neutrons has been measured and found to be 37, 58, and 5%, respectively.

Introduction

Absorption of slow neutrons by indium leads to the formation of two radioactive isotopes, In^{114} and In^{116}. The isotope In^{114} has a half-life of 48 days while the isotope In^{116} has two isomers with half-lives of 13 sec. and 54 min. The total capture cross-section of indium for thermal neutrons will therefore include the contributions due to these three different radioactive periods.

A survey of the available literature gives no exact data on the relative contributions of the three periods to the total capture cross-section for thermal neutrons. The following work was therefore performed with this end in view. The neutron source employed consisted of 250 mgm. of radium mixed with beryllium powder and was always placed at the centre of a paraffin cylinder of 8 cm. thickness and 20 cm. diameter. The thin-walled counter of 0.14 mm. wall thickness and the scaling circuit used throughout the experiments were the same as those described in an earlier paper (2). The indium detector of 5 by 2.4 cm. was made from a piece of pure indium rolled to uniform thickness. This detector was always irradiated on the surface of the paraffin cylinder. The measured thickness was found to be 58 mgm. per cm.^{2}, which can be considered as thin with respect to the absorbed neutrons but not with respect to the disintegration electrons.

Experiments Performed

In order to compare the initial activities, at saturation, of the three periods the experimental readings were treated in the following manner, after having first been corrected for counter background. The time of irradiation, t_s, was carefully noted and the factor required to bring the values to saturation was calculated. The time, t_d, that elapsed between the end of the irradiation and the beginning of the measurements was recorded so that the necessary

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decay factor could be obtained. Finally the time, t_m, for which the activity was followed was used to obtain the fraction of the total activation that was actually recorded. In this way the total number of impulses that would have been recorded by measuring for an infinite time beginning immediately after the end of an infinite irradiation could easily be found. If this number be called N_t we would have

$$N_t = N \cdot \frac{e^{\lambda t_d}}{1-e^{-\lambda t_m}} \cdot \frac{1}{1-e^{-\lambda t_r}}, \tag{1}$$

where N is the number of impulses recorded, corrected for the counter background and λ is the radioactive constant. Clearly the initial activity at saturation, A_0, will be given by

$$A_0 = N_t \cdot \lambda . \tag{2}$$

In the case of the 54 min. activity the time of irradiation and the time of measurement were both about two hours. The activity due to the 13 sec. period was rendered negligible by waiting three minutes between the end of the irradiation and the beginning of the measurements. A cadmium filter was used to obtain the activity due to resonance neutrons only; irradiating without the cadmium filter gave the activity due to resonance plus thermal neutrons. The value of N_t for thermal neutrons was obtained by subtracting from the value of N_t found for resonance plus thermal neutrons the value found for resonance neutrons only. The experiments were repeated twice and gave very consistent results. The mean value of N_t for thermal neutrons so found was 1.03×10^4.

For the 13 sec. period, the activity was measured for 30 sec. beginning 5 sec. after an irradiation of 30 sec. The readings with and without the cadmium filter were repeated 100 times. The value of N_t for thermal neutrons calculated from the means and the times involved gave 43.2.

The 48 day activity due to resonance neutrons only was found to be negligible although the detector was irradiated for 10 days. An irradiation of 11 days without the cadmium filter therefore gave the activity due to thermal neutrons only. The radioactivity due to the shorter periods was eliminated by waiting eight hours before beginning the measurements, which were followed for four days. The value of N_t for thermal neutrons calculated from Formula (1) was 1.67×10^6.

Results

The value of A_0 calculated from Formula (2) cannot be used as such since corrections must first be made for the absorption of the disintegration electrons in the counter walls and in the detector itself. If k denotes the absorption coefficient of the electrons and δ_c the thickness of the Pyrex counter wall, the correction factor for absorption by the counter is simply $e^{k.\delta c.}$. The correction factor for absorption in the indium itself was calculated on the assumption that the electrons were uniformly emitted throughout the thickness of the

detector; this assumption is valid, as the detector is thin with respect to the neutrons. If δ be the thickness of the indium this correction factor is obviously given by

$$k\delta \cdot \frac{1}{1-e^{-k\delta}}.$$

The final values corrected as indicated above are included in Table I, which gives the percentage contributions of the different periods to σ, the total capture cross-section of indium for thermal neutrons.

TABLE I

CONTRIBUTIONS OF INDIUM PERIODS TO THE CAPTURE CROSS-SECTION FOR THERMAL NEUTRONS

Period	λ, min.$^{-1}$	N_t	A_0, impulses per min.	k, cm.^{2}/gm.	$\frac{k.\delta}{1-e^{-k\delta}}$	$e^{k\delta c}$	A_0, impulses per min., corrected	% contribution to σ
13 sec.	3.20	43.2	138	3.8	1.11	1.12	173	37
54 min.	1.28×10^{-2}	1.03×10^{4}	133	12	1.40	1.45	270	58
48 days	1.00×10^{-5}	1.67×10^{6}	16.7	5.8	1.18	1.20	24	5

The values of the absorption coefficients of the electrons were obtained from the absorption curves given in papers by J. L. Lawson and J. M. Cork (4) and by L. M. Langer, A. C. G. Mitchell, and P. W. McDaniel (3).

Conclusions

The absorption coefficients as obtained from the references given above are for absorption in aluminium. This therefore introduces an error in the results of Table I, since the author assumed that the absorption coefficient in indium and Pyrex would not be very different from that in aluminium. Moreover, the absorption curves are not perfect exponentials so that only the upper part of these curves were used to calculate the values of k. This procedure is justified, as the indium detector is quite thin, but it still introduces a small error in the values obtained. Finally it must be noted that the absorption coefficients for the disintegration electrons are to a large extent dependent on the geometrical arrangement. The use, therefore, of the coefficients as found by Lawson and Cork and by Langer, Mitchell, and McDaniel may introduce errors of 10 to 20% in the values of k. These corrections, however, do not seriously affect the final results, as was proved by a simple calculation. The author first used 15 cm.^{2} per gm. as the absorption coefficient of the electrons of the 54 min. activity, this value being taken from a paper by Amaldi and others (1). In spite of this 25% increase in the value of k the relative contribution of the 54 min. activity was increased by

only 3%. It is therefore reasonable to conclude that the small corrections would not change the results given in Table I to any appreciable extent.

It should also be noted that the resonance activity acquired by the indium detector when the cadmium filter is used is lower than the resonance activity acquired by the detector when the total activity, resonance plus thermal, is measured. This phenomenon is due to the partial overlapping of the resonance regions of indium and cadmium. The correction, however, was found to affect the final results by less than 5%, and was therefore neglected.

The ratio of the contribution of the 54 min. activity to that of the 48 day activity taken from the author's results is 11.6. This value does not agree with that obtained by Sinma and Yamasaki (5) who get 5.0. This discrepancy is partially due to the large statistical error in the measurements on the 48 day activity, but this explanation cannot wholly account for the large difference between the values for the ratio. Unfortunately the capture cross-section of indium for thermal neutrons is not accurately known, so that the real source of the discrepancy cannot be stated.

Acknowledgment

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